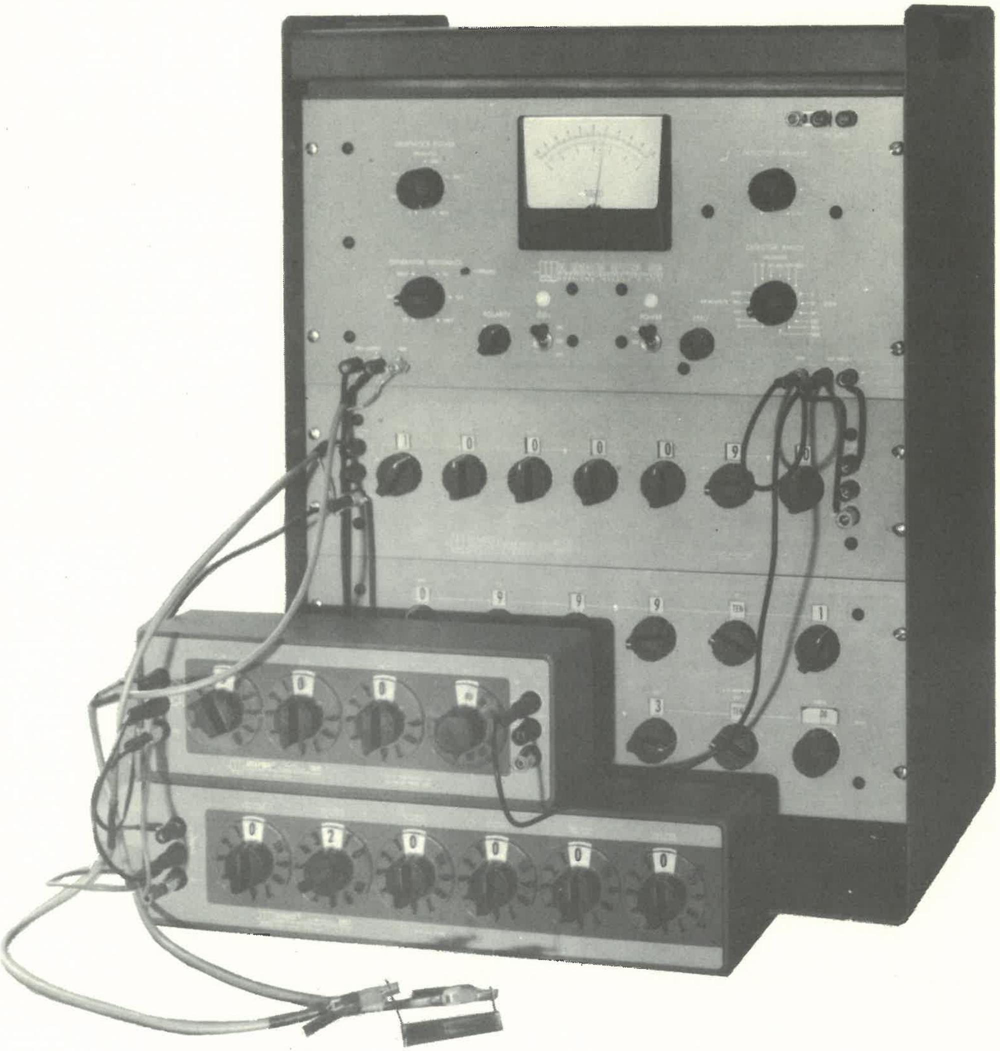
esi® Engineering Bulletin

Electro Scientific Industries
7524 S. W. MACADAM AVE. • PORTLAND 19, OREGON

BRIDGES
AND
ACCESSORIES
no. 38

JUNE 1963

# A RESISTANCE BRIDGE MADE FROM A VOLTAGE DIVIDER



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# A RESISTANCE BRIDGE MADE FROM A VOLTAGE DIVIDER

## HOW TO MAKE A BRIDGE

The high resolution and linearity accuracy of a resistive voltage divider can be used to make direct reading resistance measurements.* The circuit shown in Figure 1 will permit the measurement of the unknown resistor $R_U$. The balance equations for finding the value of $R_U$ are given in Equations 1 and 3. Equation 2 is a restriction on the fixed resistances of the bridge which gives a zero divider reading for a zero value of unknown resistance. Equation 3 gives the value of the unknown resistance when Equation 2 has been satisfied and the divider setting is adjusted to give a null on the detector.

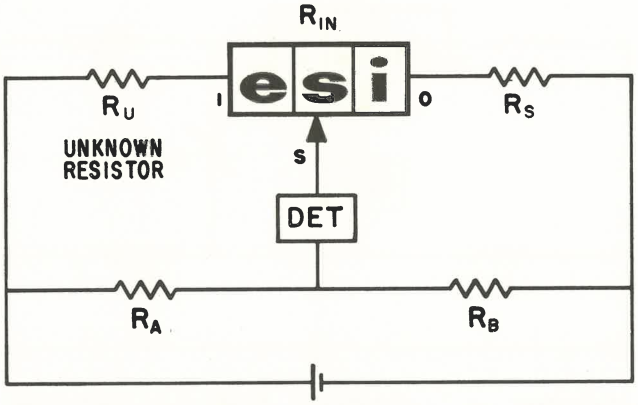

FIGURE 1. MEASUREMENT CIRCUIT

## BALANCE EQUATION

$$R_U = \left(\frac{R_A R_S}{R_B} - R_{IN}\right) + sR_{IN}\left(1 + \frac{R_A}{R_B}\right) \qquad (1)$$

$R_U$ – UNKNOWN RESISTOR TO BE MEASURED
$R_A, R_B, R_S$ – FIXED RESISTORS
$R_{IN}$ – FIXED INPUT RESISTANCE OF DIVIDER
$s$ – DIVIDER SETTING $(0<s<1)$

## RESTRICTION ON FIXED RESISTORS

(FOR $s=0$ WHEN $R=0$)

$$R_A R_S = R_B R_{IN} \qquad (2)$$

## SIMPLIFIED BALANCE EQUATION

(WHEN EQUATION (2) IS SATISFIED)

$$R_U = sR_{IN}\left(1 + \frac{R_A}{R_B}\right) \qquad (3)$$

A divider can be substituted for $R_A$ and $R_B$ as shown in Figure 2. The divider setting $s_O$ can be used for range changing or for setting up multiplying factors for strain guages, resistance thermometers, temperature coefficient tests, etc. The value of $R_S$ will have to be changed each time that $s_O$ is changed. The value of $R_S$ can be found by shorting the unknown terminals, setting $s$ to zero, $s_O$ to the desired ratio, and balancing the resulting bridge with $R_S$.

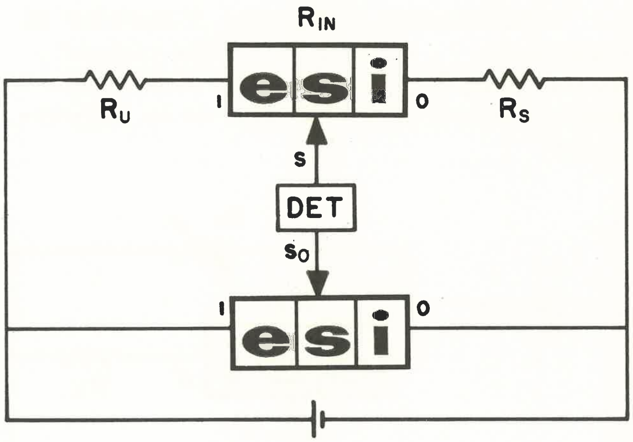

FIGURE 2. CIRCUIT USING TWO DIVIDERS

The balance equations can be rewritten in terms of the divider setting $s_O$ as shown in Equations 4, 5, and 6.

## BALANCE EQUATION

$$R_U = \left[\left(\frac{1-s_O}{s_O}\right) R_S - R_{IN}\right] + \frac{s}{s_O} R_{IN} \qquad (4)$$

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*This circuit was suggested by Charles B. Newcombe of Lockheed Missile & Space Co.

## RESTRICTION EQUATION

$$R_S = R_{IN}\left(\frac{s_0}{1-s_0}\right) \quad (5)$$

## SIMPLIFIED BALANCE EQUATION

(WHEN EQUATION (5) IS SATISFIED)

$$R_U = s\,\frac{R_{IN}}{s_0} \quad (6)$$

## HIGH RESISTANCE CIRCUITS

The value of $R_U$ at full scale divider setting ($s=1$) must be higher than $R_{IN}$ as shown by Equations 3 and 6. Shunting circuits can be used to reach low resistance values. Each has certain advantages and disadvantages.

## LOW RESISTANCE CIRCUITS

The circuit of Figure 3 results in Equations 7, 8, and 9. This circuit, by varying $R_P$, changes the full scale value without altering the zero adjustment.

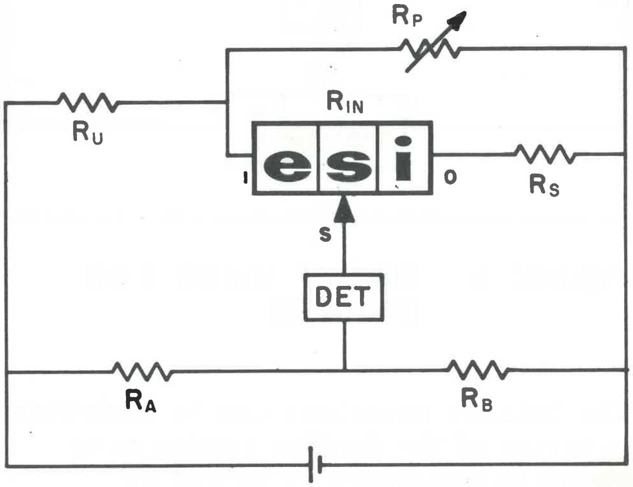

FIGURE 3. CIRCUIT FOR INDEPENDENT FULL SCALE SETTING

## BALANCE EQUATION

$$R_U = sR_{IN}\,\frac{R_P}{R_{IN}+R_S+R_P}\left(1+\frac{R_A}{R_B}\right)+\left(\frac{R_A R_S}{R_B}-R_{IN}\right) \quad (7)$$

## RESTRICTION EQUATION

$$R_A R_S = R_B R_{IN} \quad (8)$$

## SIMPLIFIED BALANCE EQUATION

$$R_U = sR_{IN}\left(1+\frac{R_A}{R_B}\right)\left(\frac{1}{1+\frac{R_{IN}+R_S}{R_P}}\right) \quad (9)$$

The circuit of Figure 4 results in Equations 10, 11, and 12. This circuit, by varying $R_D$, changes the full scale value for either high or low resistance measurements without altering the zero setting.

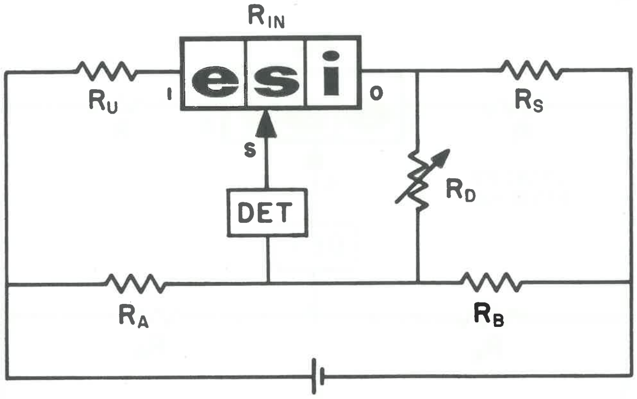

FIGURE 4 CIRCUIT FOR DEVIATION ADJUSTMENT

## BALANCE EQUATION

$$R_U = sR_{IN}\left[\frac{R_A}{R_B}\left(\frac{R_S+R_B+R_D}{R_D}\right)+1\right]+\left(\frac{R_A R_S}{R_B}-R_{IN}\right) \quad (10)$$

## RESTRICTION EQUATION

$$R_A R_S = R_B R_{IN} \quad (11)$$

## SIMPLIFIED BALANCE EQUATION

$$R_U = sR_{IN}\left(1+\frac{R_A}{R_B}\right)\left(1+\frac{R_A(R_S+R_B)}{R_D(R_A+R_B)}\right) \quad (12)$$

The circuit of Figure 5 results in Equations 13, 14, and 15. This circuit, by varying $R_S$, changes the zero setting without altering the total resistance range.

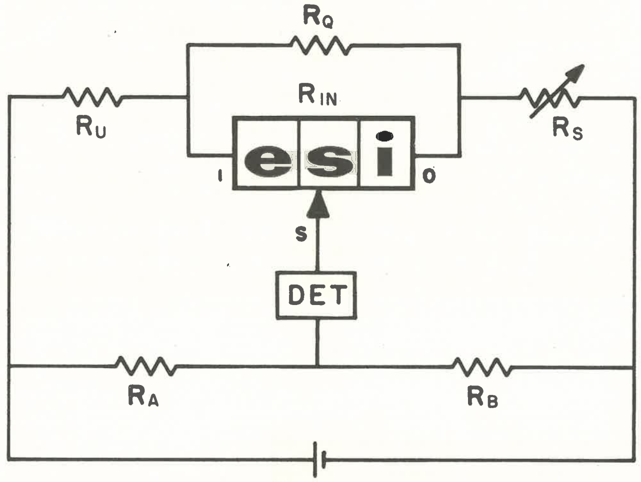

**FIGURE 5. CIRCUIT FOR INDEPENDENT ZERO SETTING**

## BALANCE EQUATION

$$R_U = \left(\frac{R_A R_S}{R_B} - \frac{R_Q R_{IN}}{R_Q + R_{IN}}\right) + s\left(\frac{R_Q R_{IN}}{R_Q + R_{IN}}\right)\left(\frac{R_A + R_B}{R_B}\right) \qquad (13)$$

## RESTRICTION EQUATION

$$\frac{R_B}{R_A R_S} = \frac{1}{R_Q} + \frac{1}{R_{IN}} \qquad (14)$$

## SIMPLIFIED BALANCE EQUATION

$$R_U = sR_{IN}\left(1 + \frac{R_A}{R_B}\right)\left(\frac{1}{1 + \frac{R_{IN}}{R_Q}}\right) \qquad (15)$$

Note that an addition to $R_U$ such as lead and contact resistances can be compensated by changing $R_S$ without changing the ratios in the simplified balance equation.

## CIRCUIT IMPROVEMENTS

The usefulness of the circuit can be extended by several modifications. The range can be changed by changing $R_{IN}$, the ratio $R_A/R_B$ or both. Four-terminal connections can be used to improve low resistance accuracy by reducing the effects of lead and contact resistance. Fixed amounts of $R_U$ (zero resistance for example) can be added or subtracted from the measurement circuit by changing $R_S$.

## HOW THE CIRCUIT WORKS

A simple geometrical construction can be used to show how the bridge operates.

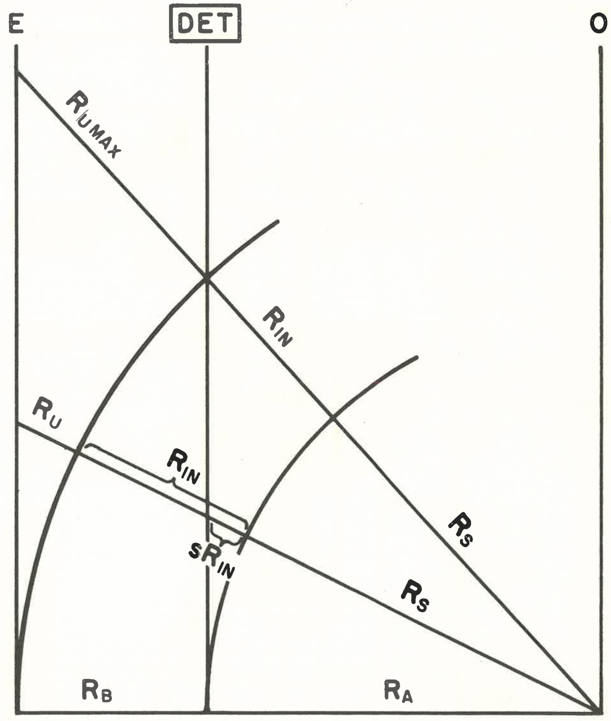

**FIGURE 6. VOLTAGE DIAGRAM**

Figure 6 is a voltage diagram showing the voltages across each of the resistors in the circuit. When $R_U$ equals zero the voltages across $R_{IN}$ and $R_B$ are equal. When $R_U$ is added in series with $R_{IN}$ and $R_S$ the voltage divides in proportion to the resistance. This can be shown geometrically by projecting the resistance sum onto the input voltage graph. To get a balance, the divider setting needs to be moved. The diagram shows that the voltage generated by the setting times $R_{IN}$ is proportional to the voltage generated by the unknown resistance.

## A BRIDGE FOR MEASURING FROM 10 MICROHMS TO 100 MEGOHMS

The divider bridge circuit can be used to make a practical measuring system for a wide range of resistance values. A practical circuit is given here only as a suggestion of some of the possible uses of the divider as a bridge element. With precision components the circuit of Figure 7 will be comparable to a good Wheatstone bridge without adjustment. If zero and full scale setting controls are added a highly accurate comparison bridge will result. The four-terminal connections shown will reduce lead and contact resistance effects when the divider is at low settings. By connecting terminal 1 and 2 together and 3 and 4 together, a two-terminal bridge can be made which will have its full scale accuracy unaffected by changes in zero resistance.

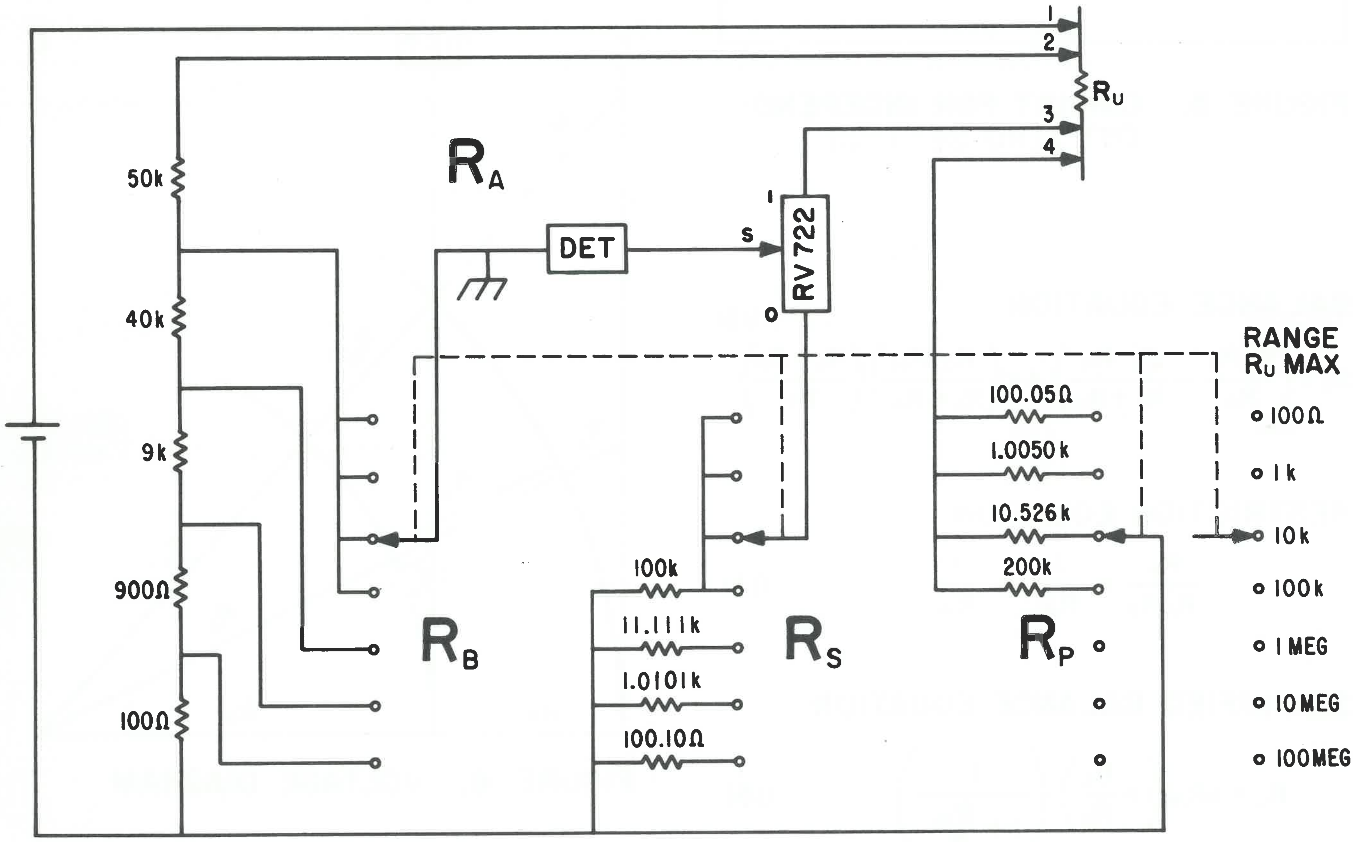

FIGURE 7. BRIDGE CIRCUIT

# BRIDGE OPERATING INSTRUCTIONS the esi way

Connect the test leads to the unknown resistor to be measured.

Balance the bridge with the divider dials.

Multiply the divider setting by the value of $R_{UMAX}$ for the range used to find the measured resistance value of $R_U$.

For higher accuracy measure the zero resistance of the leads and subtract from the measured value.

## CALIBRATION FOR PRECISION MEASUREMENT

Short the test leads together.

Set the divider to zero.

Adjust $R_S$ for a detector null.

This calibrates the zero divider setting.

Connect a certified resistor to the unknown terminals.

Any certified resistor within the bridge range having a value within a factor-of-ten of the resistor to be measured.

Set the range and divider dials to the certified value of the certified resistor.

Adjust $R_P$ for a null.

This calibrates full scale without disturbing the zero adjustment.

On the high ranges a calibration adjustment $R_P$ can be added by changing the ratio $R_A/R_B$.